ORIGINAL ARTICLE

Concentrations of Trace Elements in Bottled Water Consumed in Angono, Philippines

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ABSTRACT

Introduction. We analyzed the concentrations of the trace elements [chromium (Cr), arsenic (As), cadmium (Cd), cesium (Cs), lead (Pb), thorium (Th), and uranium (U)] in commercial bottled water consumed in the town of Angono, Rizal province, Luzon island, Philippines to evaluate the health risks of the trace elements in drinking water. There are some arguments that water resources available in the Philippines are heavily polluted by various materials, in particular heavy metal elements.

Method. The concentrations of seven trace elements in commercial bottled water produced and consumed in the Philippines were analyzed using a solution nebulization inductively coupled plasma mass spectrometry (SN–ICP–MS).

Result. The concentrations of the trace elements except for Cs, which does not yet have a WHO guideline value, in the locally produced bottled water were below the WHO guideline values. The Cs concentrations (<0.6 μg/L) of the bottled water of the Philippines were generally similar to those of the bottled water produced and consumed in other countries such as Japan, China, and Indonesia.

Conclusion. The concentrations of trace elements in bottled water consumed in Angono, Philippines can be regarded as being at safe levels, as well as those of daily life water (i.e. tap, well, and spring water) consumed in the said town.

Key Words: Philippines, Angono, bottled water, trace element, health risk

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INTRODUCTION

An evaluation of the health risks from drinking water is important for all countries. We have analyzed the concentrations of the trace elements [chromium (Cr), arsenic (As), cadmium (Cd), cesium (Cs), lead (Pb), thorium (Th), and uranium (U)] in daily life water (i.e., tap, well, and spring water) consumed in the town of Angono, Rizal province, Luzon island, Philippines, in addition to the water samples of Angono River and Laguna Lake, by using a solution nebulization inductively coupled plasma mass spectrometry (SN–ICP–MS) to evaluate the health risks of the trace elements in daily life water.[1] Some elements such as Cr, As, Cd, Pb. and U can cause biochemical toxicities to the human body, and radioactive elements such as Th and U can also present radiological hazards. The WHO guideline values are as follows: Cr: 50 μg/L, As: 10 μg/L, Cd: 3 μg/L, Pb: 10 μg/L, and U: 30 μg/L.[2] The WHO guideline value for ^{232}Th in drinking water is 1 Bq/L, which is equivalent to 250 μg/L.[2] There is no WHO guideline value for the concentration of

Cs. The standard values for As, Cd, and Pb of the Philippine National Standards for Drinking-Water (PNSDW) updated in 2016[3] are the same as the WHO guideline values.[2]

There are some arguments that water resources available in the Philippines are heavily polluted by various materials, in particular heavy elements mentioned above. For example, Saito and Nakano[4] and Kada[5] argued that various types of water available around/in Laguna Lake are contaminated by toxic metals such as Pb. Moreover, Solidum[6] analyzed 13 drinking water samples taken from different restaurants in Metro Manila using atomic absorption spectrometry (AAS), to determine the concentrations of Pb and Cd. Solidum[6] reported that the analytical values of Pb and Cd were 0.193 mg/L (1σ: 0.0544 mg/L) and 0.0186 mg/L (1σ: 0.0241 mg/L), respectively. These values are more than 19 and 6 times, respectively, higher than the WHO guideline values.[2] These previous studies argued that natural/drinking water in/around Metro Manila has been heavily polluted by heavy elements, in particular Pb.

However, contrary to these arguments, our analytical results of the tap water consumed in Angono except for Cs[1] were <0.5% of the WHO guideline values[2], with those of Cd being ~9% of the WHO guideline value. The concentrations of the trace elements in the purified tap water were generally lower than those of unpurified tap water samples, although there was a possibility that small amounts of Pb may have been added from the equipment used for water purification. The concentrations of the trace elements in water samples from the wells and springs in Angono were more variable than those of the tap water, and these were also significantly below the WHO guideline values.[1] The concentrations of Cs, whose guideline value has not been proposed by WHO, in all water samples were <0.3 μg/L.[1] Considering that those in European bottled water vary up to a maximum value of 415 μg/L[7], the Cs concentrations of the analyzed water samples can be regarded as sufficiently low[1]. The analytical data presented in Maruyama et al.[1] demonstrated that the concentrations of these trace elements in daily water currently consumed in Angono are at safe levels. The toxicological properties of the above-mentioned seven trace elements are briefly summarized in Maruyama et al.[1]

As the next step, the health risks of the trace elements in bottled water produced and consumed in the Philippines need to be evaluated. At present, bottled water commonly consumed in the Philippines, as well as in many other countries such as Japan and China, is regarded as "safe" drinking water. However, to evaluate the health risks from bottled water, it is necessary to check the trace-element concentrations in the bottled water consumed in the Philippines and compare these with those of the bottled water produced in other countries.

In this paper, we present the concentrations of the above-mentioned seven trace elements in bottled water consumed in Angono, Philippines in order to evaluate any health risks from these trace elements. We also compare them with those produced and consumed in the other countries such as Japan, China, and Indonesia.

METHODS

A total of nine samples of the bottled water produced in the Philippines were purchased from stores in Angono between October 9 and 12, 2015. These bottled water samples were kept at a few degrees Celsius in a cold box and refrigerator immediately after sampling, until preparation for instrumental analyses in Japan. The bottled water produced in Japan (8 samples), Spain (1), and France (1) were obtained in Japan during FY 2015. Those produced in South Korea (2 samples), China (9), and Indonesia (5) were obtained from the said countries during FY 2015. All bottled water samples were kept in the refrigerator just before the analyses.

The quantitative analyses of seven elements (Cr, As, Cd, Cs, Pb, Th, and U) in the water samples except for those obtained in Indonesia were carried out using a Thermo Fisher Scientific iCAP Qc ICP–MS at Kyoto University. All bottled water samples were not filtered before the analyses. The additional details of the analytical procedures are described in Maruyama et al.[1]

The quantitative analyses of seven trace elements in the bottle water samples obtained in Indonesia were carried out using an Agilent 8800 tandem ICP mass spectrometer (ICP–MS/MS) at Shimadzu Techno-Research, Inc. The flow rates of the plasma (Ar) and auxiliary gases (Ar) were set to 15 and 0.9 L/min, respectively. That of the carrier gas was 1.0 L/min. The RF power was 1550 W. The integration time and sweep number were 1 sec and 100 times, respectively. Each sample was analyzed three times. Each sample was made acidic by nitric acid, and 20 μg/L of Y, In, Tl and 100 μg/L of Te were added to them as the internal standards. Multi-element standard solutions SPEX XSTC-622 and Perkin Elmer ICP–MS Element Calibration Standard 2, were used for calibration. The determinations of the elements except for As were carried out in the single MS mode, and that of As was determined by using the MS/MS mode. The collision gases were introduced during the analyses of Cr (He; 5.0 mL/min) and As (H_2; 7.0 mL/min).

The Pb concentrations of the bottled water samples whose Th and U concentrations were shown in Maruyama et al.[8] were determined together with the Th-U concentrations during FY 2013. The analytical conditions of the Pb concentrations are described in Maruyama et al.[8] The flow rate of the collision cell gas (He + H_2) was the same as that for the analyses by using the iCAP Qc instrument (4.5–5.5 mL/min).[1]

RESULTS AND DISCUSSION

Bottled water samples of the Philippines

The concentrations of the seven trace elements in the bottled water samples of the Philippines are summarized in Table 1. The WHO guideline values[1] are also shown in Table 1. The concentrations of Cr, As, Cd, Pb, and U in all the bottled water samples analyzed in this study were substantially below the provisional guideline values proposed by WHO.[2] The highest values of the concentrations of Cr, As, Cd, Pb, and U were ~1%, ~22%, ~0.1%, ~0.5%, and ~0.3%, respectively, of the WHO guideline values.[2] (Table 1) Concentrations of Th were <0.0005% of the guideline value for the natural radionuclide ^{232}Th proposed by WHO.[2]

Concentrations of the seven trace elements in the samples PHL-BW-7 and -9 were similar to each other (Table 1). In these two samples, the concentrations of As (~2.2 μg/L) and Cs (~0.6 μg/L) were >3 and >70 times higher, respectively, than those of the other bottled water samples (<0.7 μg/L As and <0.009 μg/L Cs; Table 1). The analytical results listed in Table 1 suggest that PHL-BW-7 and -9 have been produced from a common water source. This presumption is supported by the fact that the mineral compositions described on the labels of these bottled waters match each other exactly, although the source of the water is not given. The production processes of the PHL-BW-7 and -9 waters may also be similar, given that mineral components of the water samples are maintained in the final product.

In comparison with PHL-BW-7 and -9, the samples PHL-BW-1, -2, and -8 exhibited lower concentrations of As, Cd, Cs, and U (Table 1). This suggests that these three bottled water samples may have been produced by purification processes that (partly) remove these elements from the source water. The relatively low concentrations of the elements in samples PHL-BW-4 and -6 indicate that they may also be highly purified (Table 1). The concentrations of As, Cr, and U in samples PHL-BW-3 and -5 suggest that these bottled water samples may not have been subject to a production process that completely removes these mineral components from the source water (Table 1).

Comparison with bottled water samples of the other countries

The concentrations of seven trace elements in the bottled water samples produced/consumed in the other countries are shown in Tables 2 and 3. The concentrations of these elements in the bottled water samples of the Philippines were generally similar to or much lower than those of the other countries. The tendency of the trace-element concentrations of the bottled water samples of Indonesia (Table 3) seems to be relatively similar to that of the Philippines.

Some bottled water samples of the other countries shown in Table 2 exhibited considerably higher element concentrations in comparison with those of the Philippines. For example, the U concentrations of some bottled water samples are 2–18 times higher than PHL-BW-3 (104 ng/L U; Table 1), and that of JPN-BW-3 (24 μg/L U; Table 2) was more than 230 times higher than that of PHL-BW-3. Moreover, the Cs concentration of CHN-BW-9 was 200 μg/L. This analytical value was ~320 times as high as those of PHL-BW-7 and -9 (Table 1). The concentrations of Cs in European bottled water samples vary up to a maximum value of 415 μg/L, and Cs is considered to be a characteristic component of "mineral water".[7] Thus, the Cs concentration of CHN-BW-9 was normal as bottled mineral water, and those of the bottled water of the Philippines (Table 1) was at sufficiently low levels.

Lead concentrations of bottled waters

Generally, the Pb concentration seems to be treated as one of the most important factor of the quality of the drinking water, because a high intake of Pb can cause decreased IQ in children.[9, 10] With reference to the analytical results of Saito and Nakano[4], Kada[5] argued that the Pb pollution of Laguna Lake is currently causing harmful effects on the brain development of children living around the lake. However, the trace-element concentrations, including Pb, in the daily life water consumed in Angono[1] were considerably lower

Table 1. Concentrations of seven trace elements in bottled waters produced in the Philippines

Sample name	Cr		As		Cd		Cs		Pb		Th		U	
	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)
PHL-BW-1	117.4	2.6	<9.2		<0.4		<0.3		3.1	9.9	1.2	25.3	<0.1	
PHL-BW-2	34.0	2.4	12.6	8.4	<0.4		<0.3		2.2	3.7	0.4	13.1	<0.1	
PHL-BW-3	67.9	0.6	672.9	0.6	<0.4		9.0	2.3	1.4	1.2	0.3	14.8	103.9	0.3
PHL-BW-4	36.0	3.3	<9.2		<0.4		<0.3		46.2	2.5	0.2	5.0	0.1	4.3
PHL-BW-5	495.6	0.4	235.1	1.5	<0.4		0.9	7.8	15.2	2.0	0.9	3.6	0.2	5.2
PHL-BW-6	22.8	4.5	37.6	5.5	<0.4		0.4	3.9	1.2	2.3	<0.1		0.3	3.0
PHL-BW-7	<15.4		2193.4	0.9	2.1	1.8	625.4	1.1	1.6	3.1	1.3	24.3	5.3	0.8
PHL-BW-8	17.2	91.1	57.7	4.4	<0.4		3.2	1.5	5.3	1.9	0.3	14.6	1.6	2.4
PHL-BW-9	<15.4		2231.5	0.8	2.2	7.8	634.0	0.3	0.7	16.3	0.3	11.5	5.1	0.4
WHO value[a]	50000		10000		3000		(not proposed)		10000		250000		30000	

Notes: Values with inequality signs represent that the analytical values are below the lower limits of quantitation. RSD: Relative Standard Deviation.
[a] WHO provisional guideline values for Cr, As, Cd, Pb, and U, and Th guideline value for the natural radionuclide ^{232}Th [2].

Table 2. Concentrations of seven trace elements in bottled waters produced/consumed in Japan, Spain, France, South Korea, and China

Country of water origin	Sample name	Cr		As		Cd		Cs		Pb		Th		U	
		(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)	(ng/L)	RSD (%)
Japan	JPN-BW-1	24.7	1.6	69.4	6.4	0.9	13.9	5.5	1.6	28.2	1.1	2.5	37.5	202.6	0.9
	JPN-BW-2	292.4	5.0	481.4	1.8	3.7	4.0	0.9	8.1	2.1	22.0	1.5	14.7	467.4	7.4
	JPN-BW-3	213.0	2.0	3875.6	1.5	1.2	20.7	81.6	0.7	3.3	2.3	0.6	13.5	24012.0	0.4
	JPN-BW-4	29.8	10.4	13.9	3.9	<0.3		2.0	5.8	4.6	0.6	0.4	7.4	17.4	3.0
	JPN-BW-5	21.0	3.2	<5.2		0.6	11.7	43.6	0.3	25.9	0.4	0.3	6.6	0.1	14.7
	JPN-BW-6	23.9	4.1	17.7	8.8	<0.3		<0.2		51.4	0.6	0.2	6.1	0.1	14.8
	JPN-BW-7	112.6	3.9	1624.9	1.5	6.9	4.9	91.3	1.6	<0.6		0.2	8.8	23.2	1.3
	JPN-BW-8	159.1	1.0	323.5	1.7	12.4	2.9	30.1	1.6	14.9	0.7	0.1	9.5	2.6	1.7
Spain	ESP-BW-1	66.3	1.5	166.5	1.8	<0.3		10.5	0.8	2.6	7.4	0.5	11.6	1811.2	1.1
France	FRA-BW-1	37.5	7.0	266.4	2.1	14.6	2.8	23.0	2.6	<2.4		0.7	33.1	1180.1	3.1
South Korea	KOR-BW-1	241.5	1.5	404.4	1.3	<0.3		92.2	1.1	<0.6		0.9	14.3	36.8	0.5
	KOR-BW-2	184.9	0.9	495.8	1.5	1.0	6.0	63.2	0.7	4.9	3.9	<0.2		282.7	0.2
China	CHN-BW-1	12.8	6.8	<6.6		<0.2		0.2	17.6	<0.9		1.1	31.2	<0.1	
	CHN-BW-2	647.5	0.6	121.9	2.4	3.5	3.9	10.1	1.4	1.9	2.8	<0.4		67.3	1.1
	CHN-BW-3	234.4	1.6	<6.6		<0.2		7.5	2.2	31.3	33.7	<0.4		<0.1	
	CHN-BW-4	224.6	0.4	40.5	4.5	2.5	6.9	36.0	0.8	<0.9		<0.4		1012.9	0.9
	CHN-BW-5	115.8	2.8	<6.6		<0.2		0.2	13.3	2.4	1.9	<0.4		0.1	26.9
	CHN-BW-6	568.7	1.7	157.6	2.0	20.7	3.4	256.1	0.8	27.1	1.2	<0.4		377.9	0.7
	CHN-BW-7	147.4	0.3	18.1	7.2	0.5	11.2	2.5	1.1	7.6	1.2	<0.4		242.9	1.2
	CHN-BW-8	87.4	2.4	<6.6		3.5	5.4	62.5	1.4	12.8	1.1	<0.4		15.9	1.3
	CHN-BW-9	48.8	2.9	4824.7	0.4	<0.2		199239.9	0.3	0.6	5.4	0.3	9.4	818.7	0.4

Notes: Values with inequality signs represent that the analytical values are below the lower limits of quantitation. ESP-BW-1 and FRA-BW-1 were purchased in Japan. RSD: Relative Standard Deviation.

Table 3. Concentrations of seven trace elements in bottled waters consumed in Indonesia

Sample name	Cr (ng/L)	As (ng/L)	Cd (ng/L)	Cs (ng/L)	Pb (ng/L)	Th (ng/L)	U (ng/L)
IDN-BW-1	<100	940	<5	110	<5	<2	84
IDN-BW-2	<100	3400	<5	14	15.0	<2	180
IDN-BW-3	180	580	<5	260	9.7	<2	110
IDN-BW-4	<100	200	<5	39	<5	<2	31
IDN-BW-5	<100	420	<5	160	7.0	<2	42

Note: Value with inequality signs represent that the analytical values are below the lower limits of quantitation.

than the WHO guideline values[2]. Moreover, as previously mentioned, the Pb concentrations of the bottled water of the Philippines were also substantially below the WHO guideline value.[2] Nevertheless, we need to discuss further the Pb concentrations of the bottled water of the Philippines.

Tables 4 and 5 are the Pb concentrations in a total of 92 bottled water samples consumed in Japan, whose U and Th concentrations have been published by Maruyama et al.[8] The Pb concentrations of the bottled water produced in Japan are below 134 ng/L (DBW-K-31; Table 4), with median value of 4.8 ng/L (i.e., <0.05% of the WHO guideline value[2]). Those of the bottled water samples whose sources are outside Japan are 1–24 ng/L (Table 5). In the bottled water consumed in Japan shown in Table 2 (JPN-BW-1 to -8, ESP-BW-1, and FRA-BW-1), the Pb concentrations completely overlap with the Pb-concentration range shown in Tables 4 and 5. In addition, those of the bottled water samples of South Korea, China (Table 2), and Indonesia (Table 3) are typically below ~30 ng/L.

The Pb concentrations of the bottled water samples of the Philippines (1–46 ng/L; Table 1) were very similar to those consumed/produced in the other countries. In other words, no bottled water of the Philippines exhibited extraordinary higher Pb concentration than those consumed/produced in the other countries. As with daily life water consumed in Angono[1], the Pb concentrations of the bottled water samples analyzed in this study were at harmless levels.

CONCLUSIONS

In order to evaluate the health risks posed by trace elements in the commercial bottled water consumed in Angono, Luzon island, Philippines, the concentrations of seven trace elements (Cr, As, Cd, Cs, Pb, Th, and U) in the bottled water samples had been analyzed. The concentrations of the well-known toxic elements (i.e., Cr, As, Cd, Pb, and U) and radioactive Th in all water samples were substantially below the guideline values proposed by WHO.[2] Moreover, the concentrations of these trace elements in the bottled water samples of the Philippines were of the same or lower

Table 4. Concentrations of lead in Japanese bottled waters purchased in Kyoto City (DBW-K) and those got in regions outside Kyoto City (DBW-P)

Water source		Sample	Lead concentration		Hardness on label[a]
Region	Prefecture		(ng/L)	RSD (%)	
Hokkaido		DBW-K- 1	28.5	1.5	S
		2	81.0	2.3	S
		3	2.1	4.7	MH
		DBW-P- 1	2.1	4.7	S
		2	24.6	1.1	S
		3	3.5	2.7	MH
		4	2.9	1.5	MH
		5	15.4	0.5	MH
		6	2.0	3.5	MH
		8	2.6	2.1	S
Tohoku	Iwate	DBW-K- 4	16.3	1.5	S
	Yamagata	5	3.9	2.4	S
	Fukushima	DBW-P- 9	116.7	0.6	S[b]
Kanto	Gunma	DBW-P- 10	2.9	2.7	S
	Gunma	11	2.3	3.9	S
Chubu	Niigata	DBW-K- 6	7.8	2.1	S
	Niigata	7	16.7	1.6	S
	Niigata	8	2.6	2.8	S
	Toyama	9	10.1	2.3	S
	Toyama	10	3.7	2.9	S
	Toyama	61	2.0	2.9	S
	Fukui	11	3.0	2.0	S
	Yamanashi	12	96.0	0.4	S
	Yamanashi	13	38.8	1.5	S
	Yamanashi	14	3.1	3.9	S
	Yamanashi	15	2.6	3.4	S
	Yamanashi	16	1.6	3.1	S
	Yamanashi	17	6.2	1.6	S
	Yamanashi	62	7.0	1.4	S
	Yamanashi	18	<0.7[c]		S
	Yamanashi	19	11.4	2.0	S
	Yamanashi	20	4.7	1.5	S
	Nagano	21	2.1	3.0	S
	Nagano	22	13.0	1.0	S
	Nagano	23	3.8	7.3	S
	Nagano	24	11.1	3.2	S
	Nagano	25	6.6	2.3	S
	Gifu	26	5.5	3.3	S
	Gifu	27	4.0	2.2	S
	Gifu	28	1.9	2.8	S
	Gifu	29	3.4	1.2	S
Chubu	Shizuoka	DBW-K- 30	1.7	1.3	S
	Shizuoka	31	134.2	1.3	MH
	Shizuoka	32	0.7	8.3	MH
	Yamanashi	DBW-P- 12	5.7	4.0	S
	Nagano	13	45.6	4.6	S
Kinki	Kyoto	DBW-K- 33	3.6	2.4	S
	Kyoto	34	6.0	1.0	MH
	Kyoto	35	19.2	1.0	ND
	Kyoto	36	4.8	2.4	MH
	Kyoto	37	8.4	0.9	S
	Hyogo	38	2.6	2.0	S
	Hyogo	63	27.8	1.1	MH
	Shiga	39	26.8	1.1	S
	Shiga	40	0.9	6.3	S
	Nara	41	3.1	2.0	MH
	Wakayama	42	2.3	3.4	S
	Wakayama	43	2.0	4.5	S
	Mie	44	1.9	3.2	S
	Mie	45	3.5	7.6	S
	Mie	46	20.9	0.7	VH
	Hyogo	DBW-P- 14	34.2	2.4	ND
	Mie	15	5.1	1.9	S
Chugoku & Shikoku	Tottori	DBW-K- 47	3.1	3.8	S
	Tottori	48	2.9	2.8	S
	Tottori	49	27.9	0.8	S
	Tottori	50	6.4	1.3	S
	Shimane	51	1.6	4.5	S
	Shimane	52	10.8	1.7	MH
	Shimane	64	133.5	0.7	S
	Kochi	53	<0.6[c]		MH
	Tokushima	DBW-P- 7	97.3	0.4	S
Kyusyu & Okinawa	Kumamoto	DBW-K- 54	5.1	2.6	MH
	Oita	55	3.1	3.8	S
	Miyazaki	56	3.4	3.5	S
	Miyazaki	57	39.2	1.2	MH
	Kagoshima	58	7.2	1.6	S
	Kagoshima	59	1.3	3.9	S
	Kagoshima	60	9.7	1.3	S
	Okinawa	65	2.5	7.8	H
	Oita	DBW-P- 16	11.2	1.5	S

Note: Sample names are common to those shown in Maruyama et al. [8]. RSD: Relative Standard Deviation.
[a] Classification of water hardness is based on WHO [11]. S: soft; MH: moderately hard; H: hard; VH: very hard; ND: not described on label.
[b] There was no description of hardness on a label, however a value of hardness could be found on a manufacturer's website.
[c] The analytical value is below the lower limit of quantitation.

levels in comparison with those in the bottled water samples produced/consumed in the other countries such as Japan, China, South Korea, and Indonesia. The Cs concentrations (<0.6 μg/L) were also generally consistent with those of the other countries, and could be considered to be at sufficiently low levels. Our analytical results suggest that health risks from the trace elements in the bottled water samples of the Philippines are generally low, as well as daily life water consumed in Angono.[1]

Access to safe drinking water can be considered one of the most important challenges in global environmental policies. The UN MDGs Report[12] laid out a reduction of

Table 5. Concentrations of lead in bottled waters whose water sources are outside Japan

Country	Sample		Lead concentration (ng/L)	RSD (%)	Hardness on label[a]
France	FBW-K-	1	9.3	1.4	MH
France		2	3.1	4.5	VH
France		3	13.3	1.3	VH
France		4	1.3	6.7	VH
France		5	2.0	1.6	MH
France		6	5.0	1.3	VH
Italy		7	1.4	2.0	VH
Italy		8	5.0	0.7	VH
USA		9	6.6	2.1	S
Fiji		10	23.9	2.0	MH
Canada	FBW-P-	1	<1.4[b]		S

Notes: Sample names are common to those shown in Maruyama et al. [4]. FBW-K and FBW-P represent a bottled water purchase in Kyoto City and that got in regions outside Kyoto City, respectively. RSD: Relative Standard Deviation.
[a] Classification of water hardness is based on WHO [8]. S: soft; MH: moderately hard; VH: very hard.
[b] The analytical value is below the lower limit of quantitation.

people who cannot access to improved safe drinking water as a policy goal in 2010. However, 663 million people worldwide still have to use unimproved drinking water resources, and 20% of them live in the South East Asia region.[12] Therefore, some government agencies of the Philippines such as the Laguna Lake Development Authority (LLDA) and Department of Environment and Natural Resources (DENR) have been addressing this issue.

In the above-mentioned situation, the people living in the Philippines currently seem to regard commercial bottled water as "safe" drinking water. The trace-element concentrations of the bottled waters analyzed in this study were found in the completely safe levels. However, in the future, a third-party evaluation system of the scientifically-proven quality and safety of bottled water will need to be created as with daily life water (i.e., tap, well, and spring water) examined by Maruyama et al.[1] Moreover, all the obtained information has to be broadly shared with not only bottled water producers for guarantee of safety/quality of their products but also with all people living in the Philippines. These are important future issues for maintaining the quality and safety of all types of drinking water in the Philippines.

Acknowledgments

We are grateful to the Risk Management Laboratory at Japan University of Economics for the support provided to our study. We also thank Testing and Analysis Division of Shimadzu Techno-Research, Inc. for the analyses of the trace elements in the bottled waters of Indonesia.

Statement of Authorship

Kato and Maruyama conceived the idea to measure trace element concentrations in bottled water. Kato, Maruyama, and Juban corrected bottled water samples. Maruyama and Hirata carried out analyses. Maruyama processed analytical data, and wrote the paper. All authors approved the final version submitted.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

This study was partly supported by Grants-in-Aid for Scientific Research to HK (15K00672, FY 2015-2017) and TH (A26247094, FY 2014-2019) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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